AGP: A Self-Adaptive MAC Protocol for Broadcast LANs with Bursty Traffic

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***Abstract*— A new medium access control protocol for broadcast LANs, which is capable of achieving a high performance under bursty traffic conditions, is introduced. According to the proposed protocol, the network stations are separated into groups. All the groups are granted permission to transmit in a round-robin fashion. The main objective of the grouping algorithm is to have exactly one ready station in each group. In this way, idle slots and collisions are minimized and a nearly optimal throughput-delay performance is achieved. The grouping of stations is dynamically modified at each time slot according to the network feedback information. Due to the dynamic nature of the grouping algorithm, the protocol is capable of being adapted to the sharp changes of the stations' traffic.**

I. INTRODUCTION

Channel allocation is the key problem in multiaccess networks. A broad range of Demand Assignment, Random Access and Fixed Assignment Medium Access Control (MAC) protocols have been proposed as solutions to this problem [1],[2]. However, most MAC protocols suffer from low performance when operating under bursty traffic conditions.

Recently, a new class of adaptive protocols [3]-[8] which are capable of operating efficiently in a bursty traffic environment has been introduced. Although these protocols achieve a high throughput-delay performance even when the traffic is bursty, they suffer from a significant drawback. They have difficulty in sensing the transition of a station from idle to ready state. Thus, when an idle station becomes ready, it has to wait for a relatively long period before being granted permission to transmit. Therefore, newly arriving packets suffer a significant delay, even when the offered load is low.

In this paper, a new medium access control protocol that overcomes the above drawback is introduced. According to the proposed protocol, the network stations are separated into groups. All the groups are granted permission to transmit in a round-robin fashion. The main objective of the grouping algorithm is to have exactly one ready station in each group. In this way, idle slots and collisions are minimized and a nearly optimal throughput-delay performance is achieved. The grouping of stations is dynamically modified at each time slot according to the network feedback information. Due to the dynamic nature of the grouping algorithm, the protocol is capable of being adapted to the sharp changes of the stations' traffic.

The proposed Adaptive Grouping Protocol (AGP) is applicable to a broad range of broadcast network architectures, including bus, star and wireless LANs. This paper focuses on the general principles of operation of the proposed protocol rather than on its application to specific network architectures.

The paper is organized as follows: The proposed AGP protocol is presented in Section II. Simulation results which indicate the superiority of the AGP protocol over other well-known protocols, are presented in Section III. Finally, concluding remarks are given in Section IV.

II. THE ADAPTIVE GROUPING PROTOCOL

Let $A = \{a_1, \ldots, a_N\}$ be the set of stations, where N is the number of stations. The stations communicate via a slotted broadcast channel. Each station is provided with a waiting queue of length Q, where the arriving packets are buffered before being transmitted. The traffic which is offered to the stations is assumed to be bursty. Thus, each station can be in one of two states: active or idle. When a station is active it has one packet arrival at each time slot. On the other hand, when a station is idle it has no packet arrivals. Each station operates independently from the others and has no knowledge of their states.

According to the proposed AGP protocol, the set of stations A is divided into N subsets $A_1, A_2, \ldots, A_N$ with: $A_1 \cup A_2 \cup \ldots \cup A_N = A$ and $A_1 \cap A_2 \cap \ldots \cap A_N = \emptyset$. Some of the subsets $A_i (i = 1, \ldots, N)$ may be empty sets. All the nonempty subsets are granted permission to transmit in a round-robin fashion. The main objective of AGP is to have exactly one ready station in each nonempty subset. In this way, idle slots and collisions are minimized and the throughput-delay performance is significantly improved.

In order to achieve the above objective, the grouping of station into subsets is updated at each time slot, according to the network feedback information in line with the following rules:

1) If the previous time slot t was idle then the subset $A(t)$ which was granted permission to transmit in this time slot is assumed to contain no ready stations and consequently, it is merged with a nonempty subset.

2) If a collision took place during the previous time slot t, then $A(t)$ is assumed to contain more than one ready

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station and consequently it is split into two subsets of equal size in an effort to avoid further collisions. Optimal splitting requires those stations which had the collision to be assigned to different groups. In the present protocol this feature is not implemented in order to preserve simplicity. Such a smart splitting can be implemented in a future protocol.

3) If a successful transmission took place during the previous slot then the grouping of stations into subsets is assumed to be satisfactory and remains invariant.

All the stations execute the same grouping algorithm and, due to the broadcast nature of the stations, the feedback is common for all the stations. Therefore, all the stations arrive at the same conclusion on which subset of stations is granted permission to transmit at each time slot.

In the presence of inconsistent feedback (e.g. in wireless LANs) the group information can be different for each node. In this case, which is not examined in the present paper, the performance of feedback-based protocols is slightly degraded [4],[5].

The algorithmic description of the AGP protocol is presented below. In the following description, the network feedback information at time slot t is: $slot(t) \in \{success, idle, collision\}$:

PROCEDURE AGP;
REPEAT
 $t := t + 1$;
 All stations in $A_i(t)$ are granted permission to transmit in slot t;
 If $slot(t) = idle$ then
 BEGIN
  $k := i$; repeat $k := (k \bmod N) + 1$; until (($A_k(t) \neq \emptyset$) or ($k = i$));
  if $k \neq i$ then
  BEGIN (* Merge A_i with a nonempty set *)
   $A_k(t+1) := A_k(t) \cup A_i(t)$;
   $A_i(t+1) := \emptyset$;
  END
  repeat $i := (i \bmod N) + 1$; until ($A_i(t+1) \neq \emptyset$);
 END
 else if $slot(t) = collision$ then
 BEGIN
  $k := i$; repeat $k := (k \bmod N) + 1$; until (($A_k(t) = \emptyset$) or ($k = i$));
  if $k \neq i$ then
  BEGIN (* Split A_i into two sets *)
   $A_k(t+1) := \{a_{i,1}(t), \ldots, a_{i,\lceil \frac{|A_i(t)|}{2} \rceil}(t)\}$;
   $A_i(t+1) := A_i(t) - A_k(t+1)$;
  END
 END
 else if $slot(t) = success$ then
 BEGIN
  repeat $i := (i \bmod N) + 1$; until ($A_i(t+1) \neq \emptyset$);
 END
FOREVER;

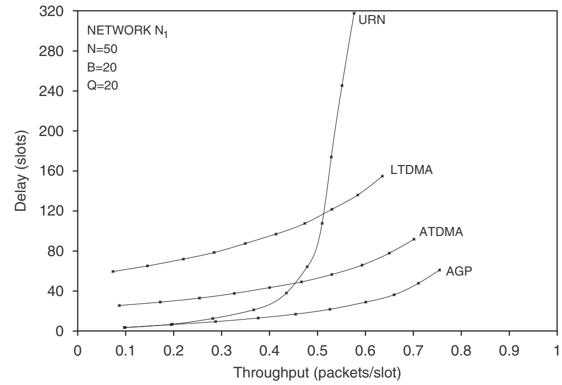

Fig. 1. The Delay vs Throughput characteristics of AGP, ATDMA, LTDMA and URN when applied to network N_1.

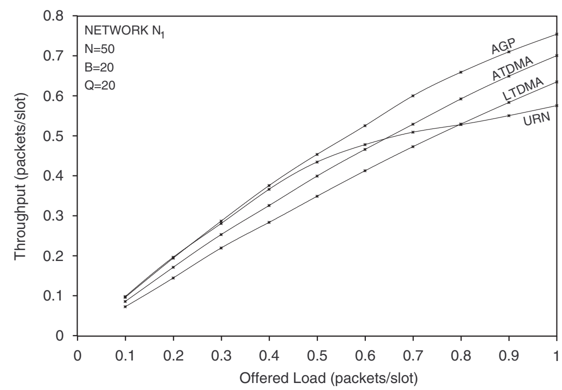

Fig. 2. The Throughput vs Offered Load characteristics of AGP, ATDMA, LTDMA and URN when applied to network N_1.

III. SIMULATION RESULTS

In the following, the proposed AGP protocol is compared to protocols [3], [4] and URN [10]. LTDMA and ATDMA are adaptive protocols which use the same network feedback information which is used by the AGP scheme. Therefore, a performance comparison between the two schemes will be very helpful in evaluating the proposed AGP protocol. URN is a limited contention protocol that achieves a high performance when operating under low load conditions. This protocol can not be fairly compared to the the other three protocols because it requires additional feedback information (the number of ready users). However, a performance comparison between the proposed AGP protocol and URN could be very useful in evaluating the AGP performance under low load conditions.

The protocols which are under comparison were simulated to be applied to three networks (N_1 to N_3) under bursty traffic conditions. The bursty traffic was modelled in the same way used in [3] and [9]. Each source-node can be in one of two states S_0 and S_1. When a source-node is in state S_0 then it has no packet arrivals. When a source-node is in state S_1 then, it has exactly one a packet arrival at each time slot. Given a

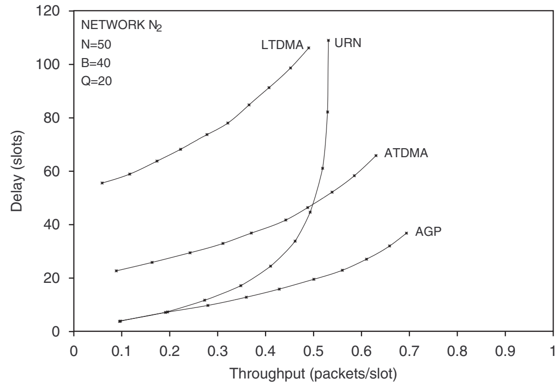

Fig. 3. The Delay vs Throughput characteristics of AGP, ATDMA, LTDMA and URN when applied to network N_2.

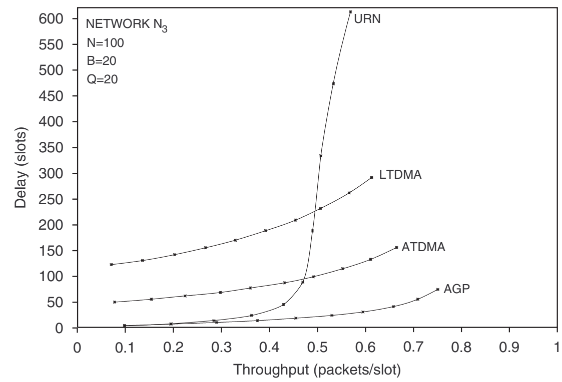

Fig. 5. The Delay vs Throughput characteristics of AGP, ATDMA, LTDMA and URN when applied to network N_3.

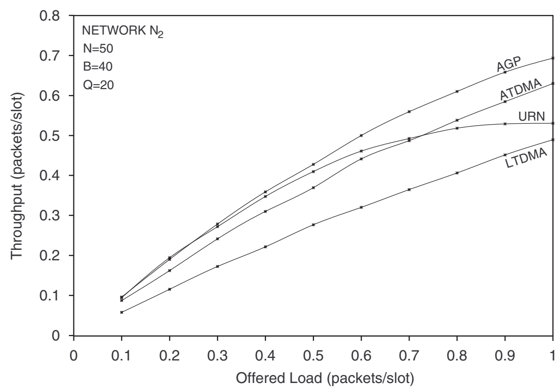

Fig. 4. The Throughput vs Offered Load characteristics of AGP, ATDMA, LTDMA and URN when applied to network N_2.

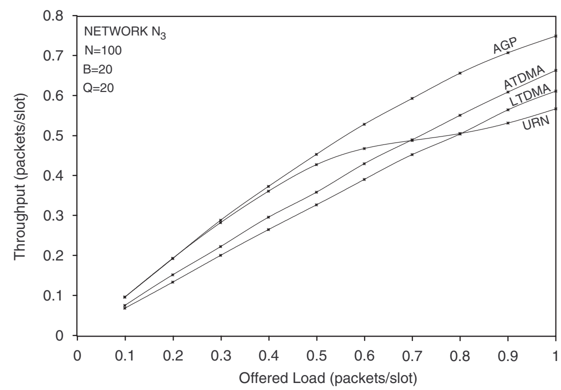

Fig. 6. The Throughput vs Offered Load characteristics of AGP, ATDMA, LTDMA and URN when applied to network N_3.

station is in state S_0 at time slot t, the probability that this station will transit to state S_1 at the next time slot is P_{01}. The transition probability from state S_1 to state S_0 is P_{10}. It can be shown that, when the load offered to the network is R packets/slot and the mean burst length is B slots, then the transition probabilities are: $P_{10} = 1/B$ and $P_{01} = \frac{R}{B(N-R)}$. Each station is provided with a FIFO queue which stores the arriving packets while they are waiting for transmission. The queue length is assumed to be equal to Q packets. A packet arriving while the queue is full, is assumed lost.

The number of stations N, the queue size Q and the mean burst length B were taken to be as follows: a) Network N_1 : $N = 50, Q = 20, B = 20$, b) Network N_2 : $N = 50, Q = 40, B = 20$, c) Network N_3 : $N = 100, Q = 20, B = 20$,

We have used the following two broadly used performance metrics in order to compare the two protocols:

1) The delay versus throughput characteristic.

2) The throughput versus offered load characteristic.

The delay versus throughput characteristics of protocols AGP, ATDMA, LTDMA and URN when applied to networks N_1 to N_3 are presented in figures 1, 3 and 5, respectively. The throughput versus load characteristics of the protocols which are under comparison when applied to networks N_1 to N_3 are presented in figures 2, 4 and 6, respectively.

The following results can be extracted from the above graphs:

1) AGP achieves a higher performance than ATDMA and LTDMA when operating under bursty traffic conditions. The three protocols use the same network feedback information. The performance advantage of proposed AGP scheme over ATDMA and LTDMA is due the fact that AGP is more efficient in sensing the transition of a station from idle to active state. On the other hand, protocols ATDMA and LTDMA are less efficient in sensing such a transition. Overall speaking, the proposed AGP protocol makes a more efficient use of the network feedback information.

2) Under low load conditions, the AGP protocol achieves a very low delay, slightly lower than the one of the URN protocol. When the load is low, both protocols degenerate to slotted ALOHA, so their performance is optimal. It should be noted that URN is based on the knowledge of the number of active stations, while AGP has no such requirement.

IV. CONCLUSION

A new MAC protocol for broadcast networks has been presented. The proposed AGP protocol, is based on the grouping of stations in such a way, that each group contains exactly one ready station. In this way, idle slots and collisions are minimized and a high throughput-delay performance is achieved. At each time slot the grouping of stations in modified according to the network feedback information. In this way, the proposed AGP protocol is capable of being adapted to the sharp changes of the stations' traffic, and consequently, it achieves a low delay and a high throughput in the dynamic bursty traffic environment.

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